Rheedea Vol. 12(2): 123-131. 2002

Classification of South Indian species of *Piper* L. (Piperaceae) by metric method

P. J. Mathew and P. M. Mathew*
Tropical Botanic Garden & Research Institute
Palode, Thiruvananthapuram – 695 562, Kerala, India
* Department of Botany, University of Kerala
Kariavattom, Thiruvananthapuram – 695 581, Kerala, India

Abstract

Thirteen indigenous species of *Piper* have been subjected to cluster analysis by metric method. They are grouped into five objectively delimited clusters based on phenetic resemblances determined in terms of values of similarity coefficients (S) using 50 characters from three disciplines (morphology, cytology and palynology). Of the five clusters I and V constitute phenons of very high ranks of 83 and 88% phenons respectively, the other two – II and IV are related each at 66% phenons, and the cluster III is a single member and one. The inter-cluster similarity values indicate that the groups I and II are most distantly affiliated, while groups I and II are least distant. The grouping based on phenetic resemblances shows some agreement with the morphological groupings proposed by Hooker (1886) and Gamble (1925) and so certain other obvious disagreements between the two exist. The notable disagreement is concerning the placement of *Piper nigrum* L.

INTRODUCTION

A great deal of confusion exists concerning the composition, interrelationships and phylogeny of the Piperaceae. The members of the family exhibit a number of anomalies, which tend to puzzle any interpretation of taxonomic and phylogenetic sequence. According to Burger (1977) the family posses a suite of characters which are and uncommon among dicots. Yuncker (1958) has pointed out that embryonic and other features of dicot nature evident in the Piperaceae more than offsets its proper classificatory treatment.

As regards the classification of the type genus *Piper* of the family Piperaceae, the pioneering taxomists of the Indian flora have pointed out great inadequacy which is mainly due to the extreme range of variability of their exomorphic characters, based on which the existing classifications of the South Indian groups has been framed. Modern classificatory procedure depend on recognition of character combinations for construction of taxonomic groups and for

separation (discrimination). Various methods and techniques are currently employed for this, ranging from neural estimates of resemblances through scatter diagrams to various mathematical coefficients. The past few years have witnessed remarkable interests in the use of metric method in taxonomy. An attempt has been made here to use this method in the classification of the South Indian *Piper*, which comprises 23 indigenous species.

MATERIALS AND METHODS

The thirteen indigenous species of *Piper* (Table 1) have been subjected to cluster analysis following the numerical methods of Sokal and Sneath (1963) and Sneath and Sokal (1973) for grouping them into sound clusters based on phenetic resemblances determined in terms of similarity coefficients. In computing the similarity coefficients between the taxonomic entities, numerical taxonomy takes into account a large number of characters drawn from different disciplines with equal value and importance given to each character. The main role of this method is to group taxa based on phenetic resemblances determined by means of similarity. A similarity matrix for the purpose was formed by two-state coding of 50 characters (Table 2) drawn from three disciplines viz., morphology, cytology and palynology with 43, 3 and 4 characters respectively. The similarity coefficients (S) of sets of pairs of the thirteen species (Operational Taxonomic Units – OTUs are computed using the equation:

$$S = \frac{NS}{NS + ND}$$

where NS = No. of positive features shared by two OTUs and ND = No. of positive features in one OTU and negative in other.

Table 1. Indigenous species of *Piper* treated as OTUs and subjected to cluster analysis

OTU No.	Name of species	OTU No.	Name of species
1.	*Piper glaeatum* C. DC.	8.	*P. barberi* Gamble
2.	*P. trichostachyon* C. DC.	9.	*P. nigrum* L.
3.	*P. longum* L.	10.	*P. hymenophyllum* Miq.
4.	*P. hapnium* Buch.-Ham.	11.	*P. argyrophyllum* Miq.
5.	*P. brachystachyum* Wall.	12.	*P. attenuatum* Buch.-Ham.
6.	*P. hookeri* Miq.	13.	*P. wightii* Miq.
7.	*P. schmidtii* Hook. f.		

Table 2. Characters of species of *Piper* studied

Sl. No.	Character	Sl. No.	Character
1.	Habit	26	Male spike diameter
2.	Vine column height	27	Female spike shape
3.	Stem surface	28	Female spike length
4.	Stem colour	29.	Female spike diameter
5.	Lateral branch habit	30	Spike fragrance
6.	Stipule shape	31.	Spike colour
7.	Petiole length	32.	Spike stalk length
8.	Leaf shape	33.	Bract type
9.	Leaf base	34.	Receptacle shape
10.	Leaf tip	35.	Stamen number
11.	Leaf colour	36.	No. of staminodes
12.	Leaf vestiture	37.	No. of stigmatic lobes
13.	Leaf texture	38.	Filament shape
14.	Leaf margin	39.	Ripe fruit colour
15.	Leaf venation	40.	Fruit shape
16.	Leaf vein number	41.	Fruit taste
17.	Lamina length	42.	Fruit size
18.	Lamina width	43.	Fruit fresh weight
19.	Lamina thickness	44.	Chromosome number (Ploidy)
20.	Leaf fresh-weight	45.	Chromosome size
21.	Leaf dry-weight	46.	Meiotic behaviour
22.	Sexuality	47.	Pollen size
23.	Spike orientation	48.	Pollen shape
24.	Male spike shape	49.	Pollen aperture
25.	Male spike length	50.	Exine ornamentation

RESULTS AND DISCUSSION

The computed 'S' values were made out into a 't x t' data matrix (Table 3). The main phenetic groups are identified by means of cluster analysis by which the OTUs are rearranged placing similar ones together. The clusters are arranged in a hierarchic dendrogram (Fig. 1), the ordinate of which indicates the magnitude of similarity coefficients at which the stem of the dendrogram joins to form higher rating taxa. The similarity indices are used as criteria of the ranks, and these values are used to delimit taxonomic groups objectively by choosing arbitrarily fixed levels of similarity.

Table 3. t x t Similarity matrix of 13 OTUs

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	100												
2	85	100											
3	34	34	100										
4	32	41	88	100									
5	49	59	66	63	100								
6	63	63	46	49	66	100							
7	59	73	41	44	66	71	100						
8	46	46	59	66	59	49	100						
9	88	83	37	34	49	56	61	49	100				
10	44	49	51	54	56	66	51	68	51	100			
11	49	545	56	54	61	66	61	59	51	80	100		
12	54	49	56	54	66	71	56	59	51	71	80	100	
13	68	63	51	49	71	71	66	59	66	66	66	76	100

The dendrogram (Fig. 1) shows that the 13 OTUs are clustered into five groups (Table 4) each of which is called a phenon, prefaced with a number indicating the level of similarity. Cluster I *(P. galeatum, P. trichostachyon, P. nigrum)* and Cluster V *(P. longum, P. hapnium)* constituted phenons of very high ranks of 83% and 88% phenons respectively. The Cluster II *(P. hookeri, P. schmidti, P. brachystachyum)* and Cluster IV *(P. hymenophyllum, P. argyrophyllum, P. attenuatum, P. wightii)* are related each at 66% phenons. Cluster III is a single member one (*P. barberi*). The inter-cluster similarity values indicate that the Cluster I and V are most distantly affiliated, and Clusters I and II are least distant.

Classification of South Indian species of *Piper* L. by metric method

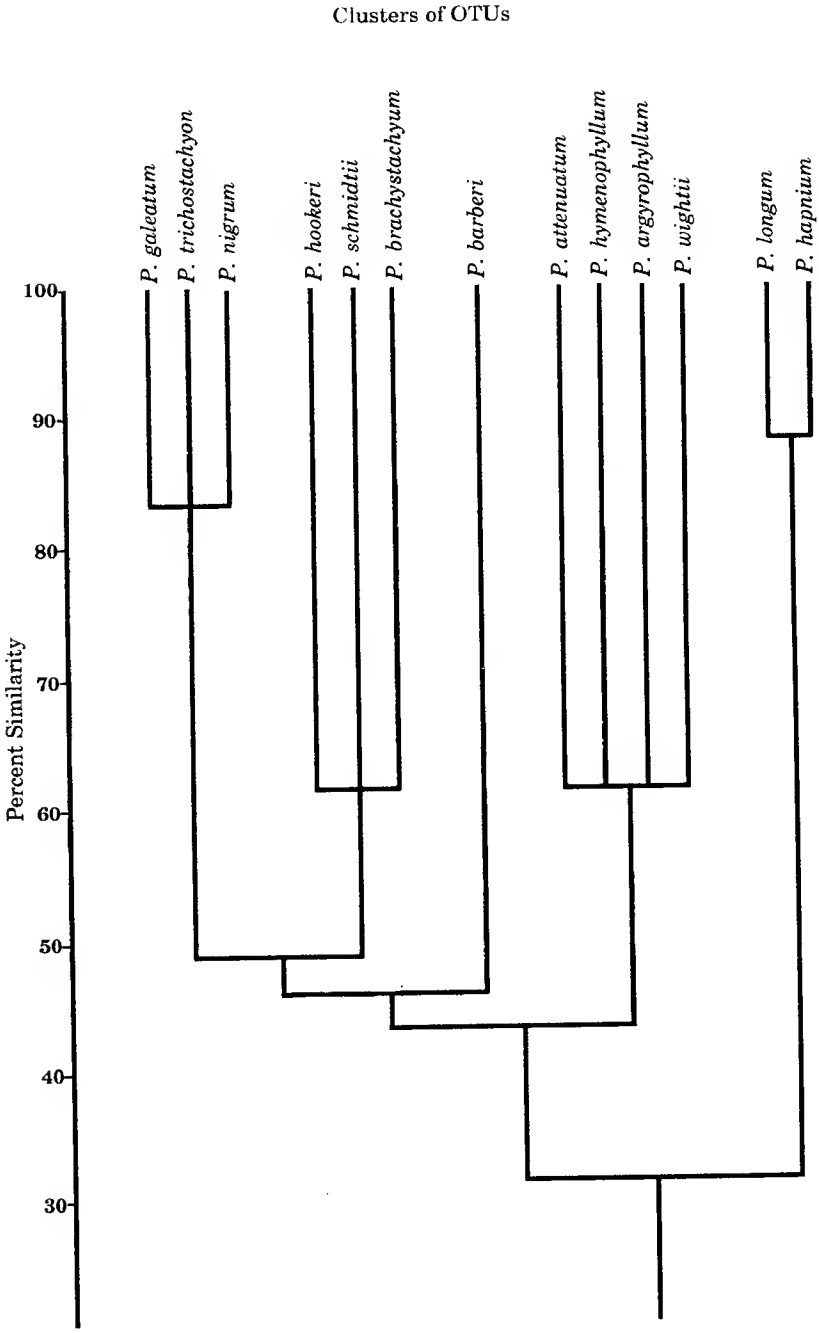

Fig. 1. Dendrogram representing the hierarchy obtained by analysis of the matrix of similarity coefficients between OTUs.

Table 4. Phenetic groups of species of *Piper* L. clustered by metric method

Clusters Phenetic groups	Names of species (OTUs)	Level of intracluster similarity (%)	Inter-clusters similarity (%)
I	*P. galeatum* *P. trichostachyon* *P. nigrum*	83	
II	*P. hookeri* *P. schmidtii* *P. brachystachyum*	66	49
III	*P. barberi*	Single member cluster	46
IV	*P. hymenophyllum* *P. argyrophyllum* *p. attenuatum* *P. wightii*	66	44
V	*P. longum* *P. hapnium*	88	32

A comparison of the composition of the present grouping based on phenetic resemblances with the existing grouping in the classifications by Hooker (1886) and Gamble (1925) which are based on handful of exomorphic characters show that there is some degree of agreement and also certain other obvious disagreement between the two (Table 5). Hooker's *Piper* sect. *Muldera (P. galeatum* and *P. trichostachyon)* and sect. *Eupiper (P. nigrum, P. attenuatum, P. hymenophyllum, P. argyrophyllum* and *P. wigtii)* as recognized by Hooker (1886) are similar to the present Cluster I and IV respectively, except for the inclusion of *P. nigrum* in sect. *Eupiper* by Hooker, which on the other hand clustered with *P. galeatum* and *P. trichostachyon* in the present Cluster I. The sections of *Piper viz., Chavica* and *Pseudochavica* (Hooker, 1886) are similar to the present Clusters V and II respectively, but differ with regard to the placement of *P. brachystachyum* which was under the sect. *Chavica*. In the present treatment, *P. brachystachyum* is grouped with *P. hookeri* and *P. schmidtii* in Cluster II.

Classification of South Indian species of *Piper* L. by metric method

Table 5. Classification of South Indian species of *Piper* according to Hooker, Gamble and Present Taxonomic grouping

Hooker (1886)	Gamble (1925)	Present Grouping
Piper Sect. **Muldera**	**Group I**	**Cluster I**
P. galeatum	*P. galeatum*	*P. galeatum*
P. trichostachyon	*P. trichostachyon*	*P. trichostachyon*
		P. nigrum
Piper Sect. **Chavica**	**Group II**	**Cluster II**
P. longum	*P. longum*	*P. hookeri*
P. hapnium	*P. hapnium*	*P. schmidtii*
P. brachystachyum	*P. brachystachyum*	*P. brachystachyum*
	P. hookeri	
	P. schmidtti	
	P. barberi	
Piper Sect. **Pseudochavica**	**Group III A**	**Cluster III**
P. hookeri	*P. nigrum*	*P. barberi*
P. schmidtii		
Piper Sect. **Eupiper**	**Group III B**	**Cluster IV**
P. nigrum	*P. hymenophyllum*	*P. attenuatum*
P. attenuatum	*P. argyrophyllum*	*P. hymenophyllum*
P. argyrophyllum	*P. attenuatum*	*P. argyrophyllum*
P. wightii	*P. wightii*	*P. wightii*
P. hymenophyllum		
		Cluster V
		P. longum
		P. hapnium

The composition of Gamble's groups I and III B is in agreement with the present Clusters I and IV respectively except for the inclusion of *P. nigrum* in Cluster I from Group IIIA. Gamble has treated *P. nigrum* as a single member in his Group IIIA on the exclusive merit of this species having flowers which are subtended by bracts adnate to the rachis. Gamble's group II is very much different from the present one. He has accommodated *P. longum, P. hapnium* and *P. barberi* along with *P. hookeri, P. schmidtii* and *P. brachystachyum* in Group II on the ground that all these species are characterised by flowers which are subtended by peltate orbicular bracts. In the present grouping, *P. longum* and *P. hapnium*, which constitute an 88% phenon, are brought together into a separate cluster (V) while *P. barberi* which does not exhibit enough phenetic resemblances to any of the other species is treated as a single member cluster (III). It may be noted that this species possesses a few very distinctive features such as craspedodromous leaf venation, very long inflorescence stalk, and leafy stipule.

Ravindran *et al.* (1992) and Rahiman and Bhagwan (1985) have attempted clustering of a few South Indian species of *Piper*, following the 'centroid linkage' method, and D^2 analysis method respectively. Their groupings agreed with the present one in certain respects especially concerning the *P. galeatum - P. trichostachyon* group. However, Ravindran *et al.* (l.c.) have clustered *P. schmidtii, P. galeatum* and *P. trichostachyon* together, and Rahiman and Bagwan in turn had clustered *P. brachystachyum* with *P. galeatum,* and *P. trichostachyon* and *P. hookeri* with *P. argyrophyllum* and *P. attenuatum.* In the treatment Rahiman and Bhagwan *P. nigrum* and *P. wightii* were brought in the same group. It may be noted that *P. nigrum* which is clustered in the present grouping with *P. galeatum* and *P. trichostachyon* has certain obvious distinction from the two species in being bisexual and unique possession of the alkaloid piperin and a set of terpenoids which contribute to the typical flavour of 'black pepper'. But in the metric method of clustering, which gives equal weight to all characters, uniqueness in a handful of traits does not matter much. In the present metric analysis, *P. nigrum* showed highly significant phenetic similarity with *P. galeatum* and *P. trichostachyon* (88%) which makes its clustering with the latter two justifiable in the taxonomic point of view. From the dendrogram (Fig. I) presented here, it may be noted that the inter-cluster distance between clusters II and IV is only marginal which is suggestive of their closer interrelationship. On the other hand, Cluser V *(P. longum* and *P. hapnium* is very distant from the rest of the groups. The two species of this cluster exhibit a number of distinctive features especially of habit (scandant shrub), stipule (leafy), spike (erect, short, cylindrical), anther filament (flat) and fruit size (very small). Although *P. brachystachyum* shares some of these features (erect spike, short female spike, and very small fruit), its habits is remarkably different from *P. longum* and *P. hapnium.* The metric analysis showed these species to have more phenetic resemblance with *P. hookeri* and *P. schmidtii.*

Acknowledgements

The authors are thankful to Prof. G. Sreekandan Nair, Director, Tropical Botanic Garden and Research Institute, Thiruvananthapuram, Kerala for providing facilities, and encouragement.

Classification of South Indian species of *Piper* L. by metric method

Literature cited

Burger, W. C. 1977. The Piperales and Monocots – Alternate hypothesis for the origin of Monocotyledonous flowers. *Bot. Rev.* 43: 345-383.

Gamble, J. S. 1925. Piperaceae. *In: Flora of the Presidency of Madras.* Adlard & Son Ltd., London. Vol. 2: 842-845.

Hooker, J. D. 1886. *The Flora of British India.* Vol. 5. L. Reev & Co., London. pp. 78-95.

Rahiman, B. A. & S. Bhagwan. 1985. Analysis of divergence in eight species of *Piper* using D^2 statistics. *Bot. Bull. Acad. Sinica* 26: 39-45.

Ravindran, P. N., R. Balakrishnan & K. Nirmal Babu. 1992. Numerical taxonomy of South Indian *Piper* L. (Piperaceae): Cluster analysis. *Rheedea* 2: 55-61.

Sneath, P. H. A. & R. R. Sokal. 1973. *Numerical Taxonomy.* W. H. Freeman, Sanfrancisco, USA.

Sokal, R.R. & P.H.A. Sneath. 1963. *Principles of Numerical Taxonomy.* W.H. Freeman, Sanfrancisco, USA.

Yunker, T. G. 1958. The Piperaceae – a family profile, *Brittonia* 10: 1-7.